Dr. Mohamed Salah

Ch. 5

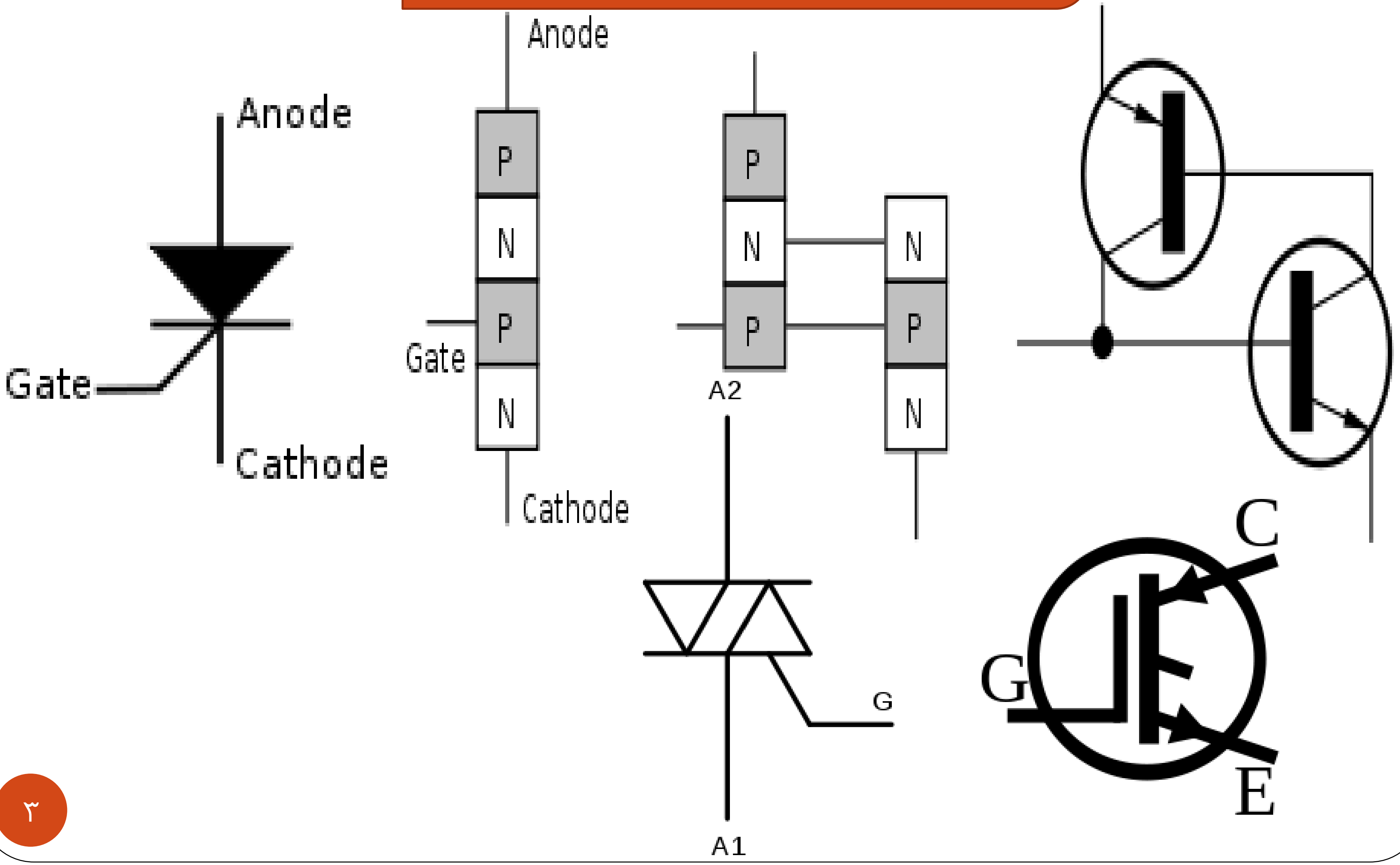
VOLTAGE CONTROLLER & SAW-TOOTH WAVE GENERATOR

Voltage Controller

A voltage controller, also called an AC voltage controller or AC regulator is an electronic module based on either thyristors, TRIACs, SCRs or IGBTs, which converts a fixed voltage, fixed frequency, AC electrical input supply to obtain variable voltage in output delivered to a resistive load.

AC voltage controllers are employed to vary the RMS value of the alternating voltage applied to a load circuit by introducing Thyristors between the load and a constant voltage ac source. The RMS value of the alternating voltage applied to a load circuit is controlled by controlling the triggering angle of the Thyristors in the ac voltage controller circuits.

Voltage Controller



Voltage Controller

There are two different types of thyristor control used in practice to control the ac power flow:

- On-Off control
- Phase control

In On-Off control technique, Thyristors are used as switches to connect the load circuit to the ac supply (source) for a few cycles of the input ac supply and then to disconnect it for few input cycles.

In phase control, the Thyristors are used as switches to connect the load circuit to the input ac supply, for a part of every input cycle. The thyristor switch is turned on for a part of every half cycle, so that input supply voltage appears across the load and then turned off during the remaining part of input half cycle to disconnect the ac supply from the load.

Voltage Controller

By controlling the phase angle or the trigger angle ‘α’ (delay angle), the output RMS voltage across the load can be controlled. The trigger delay angle ‘α’ is defined as the phase angle (the value of ωt) at which the thyristor turns on and the load current begins to flow.

Voltage Controller

Types of AC Voltage Controllers

The ac voltage controllers are classified into two types based on the type of input ac supply applied to the circuit.

- Single Phase AC Controllers.
- Three Phase AC Controllers.

The single phase ac controllers operate with single phase ac supply voltage of 230V RMS at 50Hz, while the three phase ac controllers operate with 3 phase ac supply of 400V RMS at 50Hz supply frequency.

Each type of controller may be sub-divided into:

- Uni-directional or half wave ac controller.
- Bi-directional or full wave ac controller.

Voltage Controller

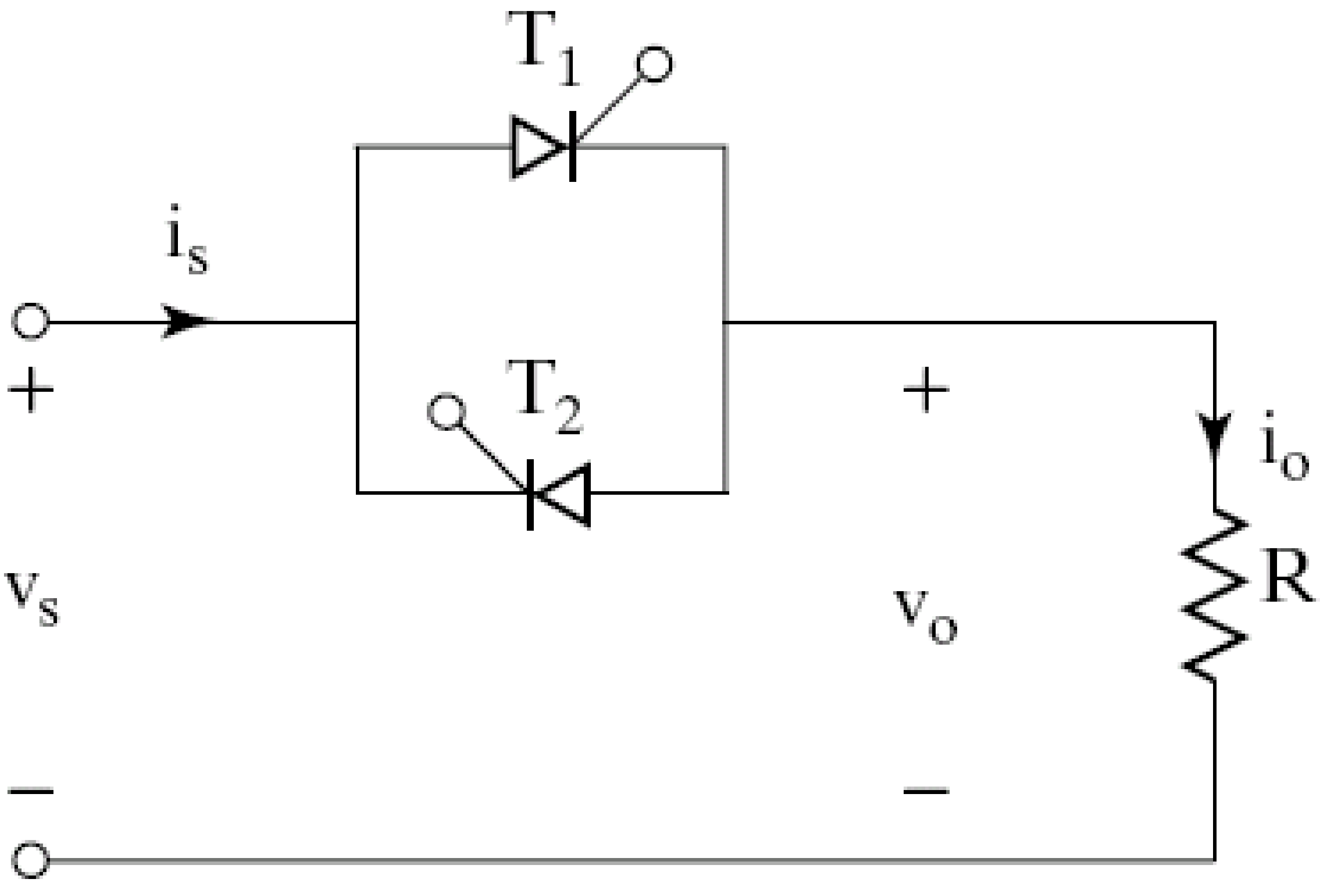
In brief different types of ac voltage controllers are:

- Single phase half wave ac voltage controller (uni-directional controller).
- Single phase full wave ac voltage controller (bi-directional controller).
- Three phase half wave ac voltage controller (uni-directional controller).
- Three phase full wave ac voltage controller (bi-directional controller).

Voltage Controller

Principle of On-Off Control Technique

(Integral Cycle Control)



Single phase full wave AC voltage controller circuit

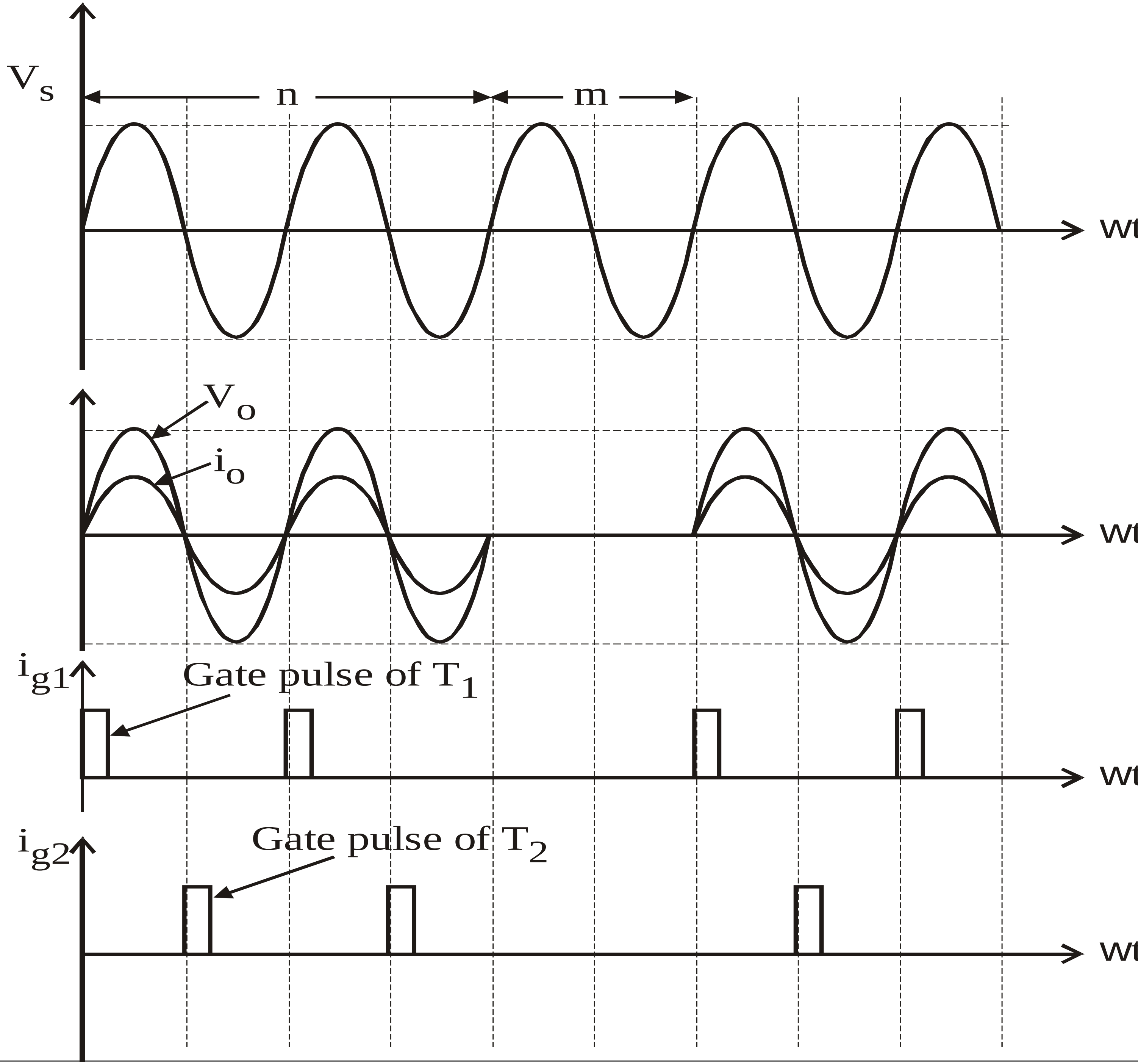
Voltage Controller

Principle of On-Off Control Technique

(Integral Cycle Control)

The thyristor switches T_1 and T_2 are turned on by applying appropriate gate trigger pulses to connect the input ac supply to the load for 'n' number of input cycles during the time interval t_{ON}. The thyristor switches T_1 and T_2 are turned off by blocking the gate trigger pulses for 'm' number of input cycles during the time interval t_{OFF}. The ac controller ON time t_{ON} usually consists of an integral number of input cycles.

This type of control is used in applications which have high mechanical inertia and high thermal time constant (Industrial heating and speed control of ac motors). Due to zero voltage and zero current switching of Thyristors, the harmonics generated by switching actions are reduced.



V_s
n
m
wt
V_o
i_o
wt
i_{g1}
Gate pulse of T_1
wt
i_{g2}
Gate pulse of T_2
wt

For a sine wave input supply voltage,

$$v_s = V_m \sin \omega t = \sqrt{2} V_S \sin \omega t \tag{54}$$

V_S = RMS value of input ac supply $V_m / \sqrt{2}$ = RMS phase supply voltage.

If the input ac supply is connected to load for ‘**n**’ number of input cycles and disconnected for ‘**m**’ number of input cycles, then

$$t_{ON} = n \times T,\ t_{OFF} = m \times T \tag{55}$$

Where $T = 1 / f$ = input cycle time (time period) and, f is the input supply frequency.

$$T_o = \text{Output time period} = (t_{ON} + t_{OFF}) = (nT + mT). \qquad (56)$$

We can show that, the output RMS voltage

$$V_{O(RMS)} = V_{i(RMS)} \sqrt{\frac{t_{ON}}{T_O}} = V_S \sqrt{\frac{t_{ON}}{T_O}} \qquad (57)$$

where $V_{i(RMS)}$ is the RMS input supply voltage = V_S. So that

$$V_{O(RMS)} = V_S \sqrt{\frac{n}{n+m}} = V_S \sqrt{k} \qquad (58)$$

where k is the duty cycle.

- **RMS Load Current**

$$I_{O(RMS)} = \frac{V_{O(RMS)}}{Z} = \frac{V_{O(RMS)}}{R_L} \qquad (59)$$

for a resistive load $Z = R_L$.

- **Output AC (Load) Power**

$$P_O = I^2_{O(RMS)} \times R_L \qquad (60)$$

- **Input Power Factor**

$$PF = \frac{P_O}{VA} = \frac{\text{output load power}}{\text{input supply volt amperes}} = \frac{P_O}{V_S I_S} \qquad (61)$$

$$PF = \frac{I^2_{O(RMS)} \times R_L}{V_{i(RMS)} \times I_{in(RMS)}}; \qquad I_S = I_{in(RMS)} = \text{RMS input supply current.}$$

The input supply current is same as the load current;

$$I_{in} = I_o = I_L$$

Hence, RMS supply current = RMS load current;

$$I_{in(RMS)} = I_{O(RMS)}$$

So that

$$PF = \frac{I^2_{O(RMS)}\ x\ R_L}{V_{i(RMS)}\ x\ I_{in(RMS)}} = \frac{V_{O\,(RMS)}}{V_{i\,(RMS)}} = \frac{V_{i\,(RMS)}\sqrt{k}}{V_{i\,(RMS)}} = \sqrt{k} \qquad (62)$$

- **The Average Current of Thyristor**

$$I_{T(Avg)} = \frac{I_m n}{\pi\left(m+n\right)} = \frac{k.I_m}{\pi}\ , \qquad (63)$$

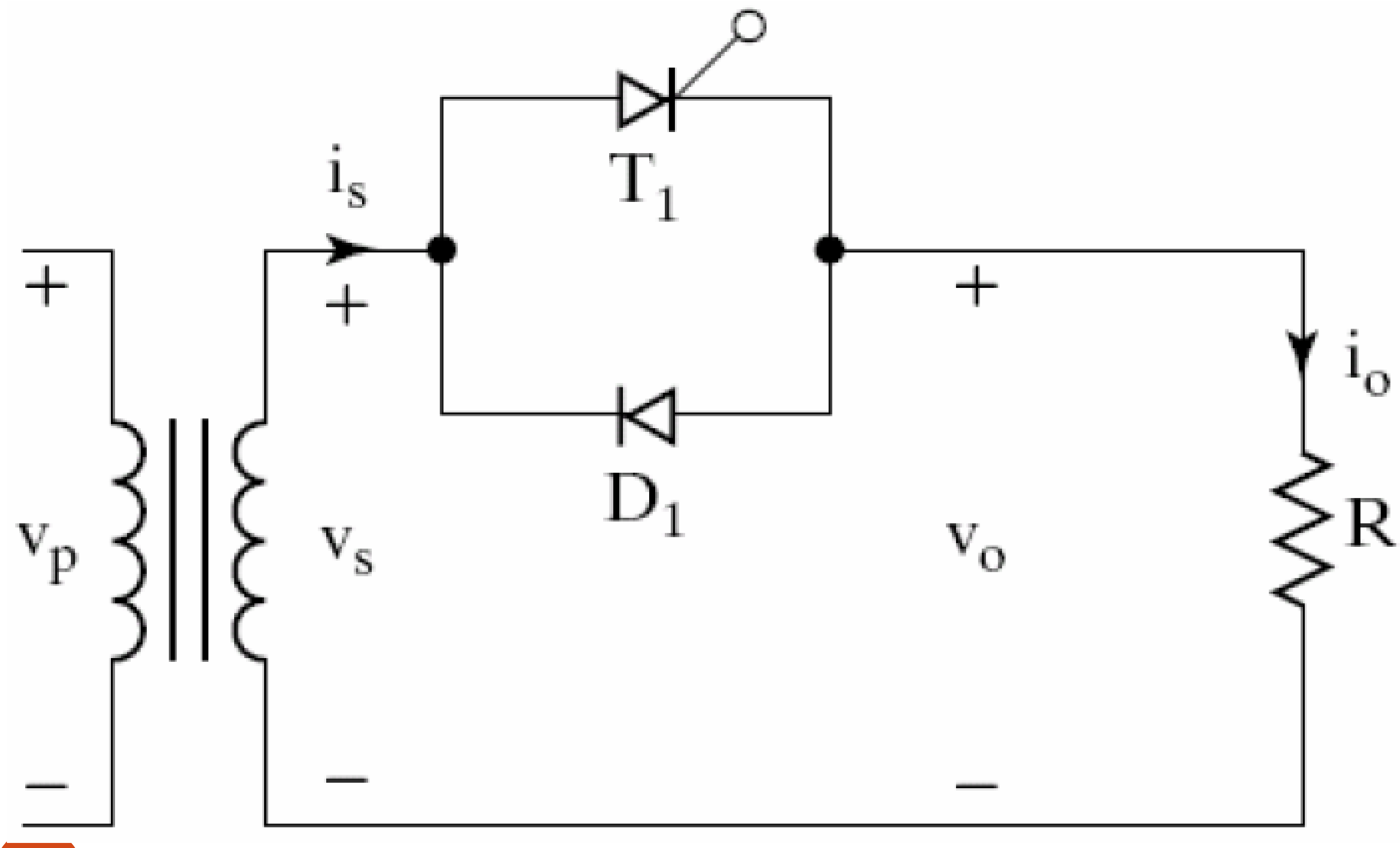
where $I_m = V_m / R_L$ = maximum or peak thyristor current.

- **RMS Current of Thyristor**

$$I_{T(RMS)} = \frac{I_m}{2}\sqrt{\frac{n}{\left(m+n\right)}} = \frac{I_m}{2}\sqrt{k} \qquad (64)$$

Voltage Controller

Principle of AC Phase Control



Half-wave AC phase controller (Unidirectional Controller)

Voltage Controller

Principle of AC Phase Control

The half wave ac controller uses one thyristor and one diode connected in parallel across each other in opposite direction that is anode of thyristor T1 is connected to the cathode of diode D1 and the cathode of T1 is connected to the anode of D1. The output voltage across the load resistor 'R' and hence the ac power flow to the load is controlled by varying the trigger angle 'α'.

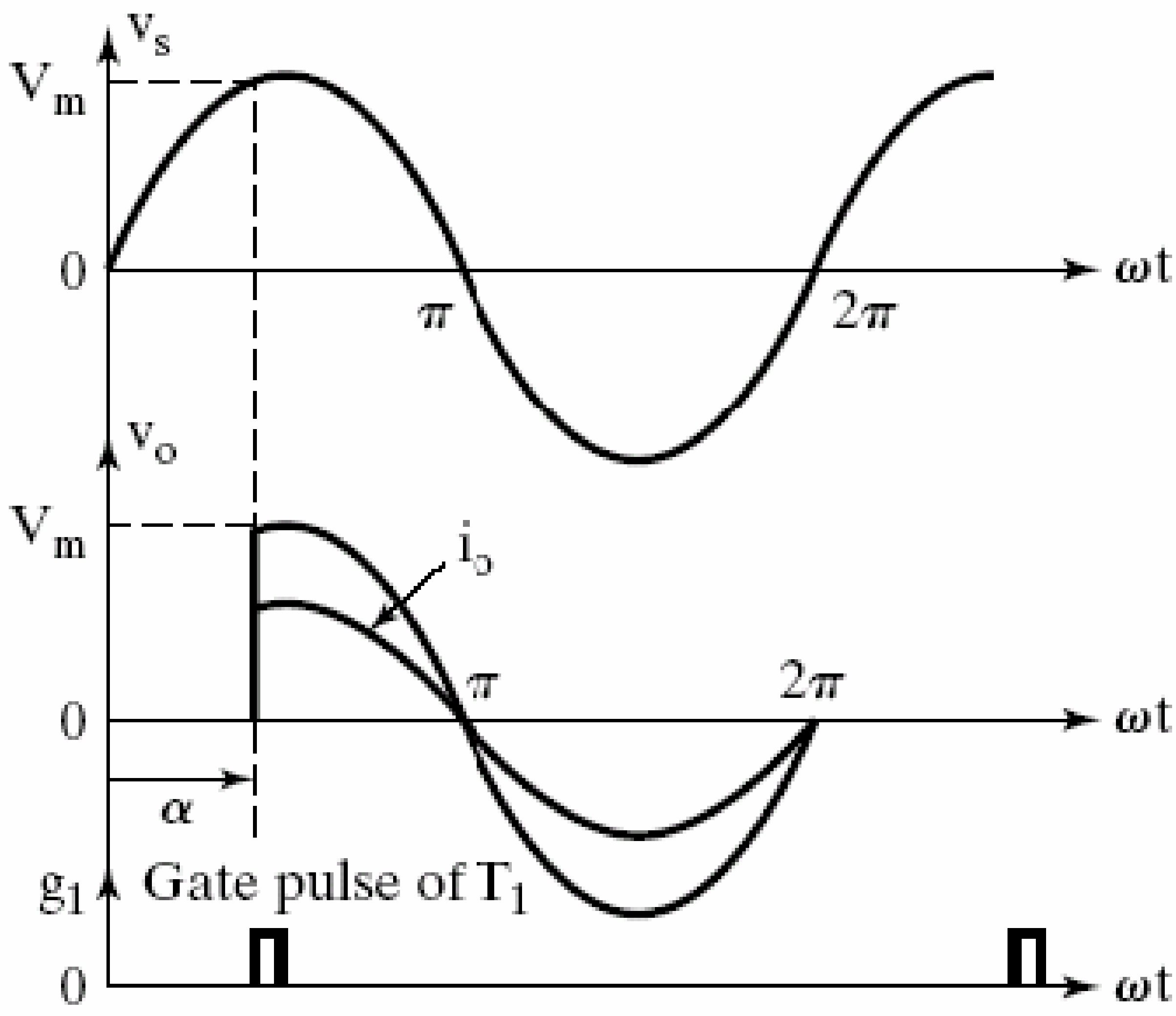
The trigger angle or the delay angle 'α' refers to the value of ω t or the instant at which the thyristor T_1 is triggered to turn it ON, by applying a suitable gate trigger pulse between the gate and cathode lead.

Voltage Controller

Principle of AC Phase Control

The thyristor T1 is forward biased during the positive half cycle of input ac supply. It can be triggered and made to conduct by applying a suitable gate trigger pulse only during the positive half cycle of input supply.

Voltage Controller



Voltage Controller

Disadvantages of Single Phase Half-Wave AC Voltage Controller

• The output load voltage has a DC component because the two halves of the output voltage waveform are not symmetrical with respect to '0' level. The input supply current waveform also has a DC component (average value) which can result in the problem of core saturation of the input supply transformer.

• The half wave ac voltage controller using a single thyristor and a single diode provides control on the thyristor only in one half cycle of the input supply. Hence ac power flow to the load can be controlled only in one half cycle.

• Half-wave ac voltage controller gives limited range of RMS output voltage control. Because the RMS value of ac output voltage can be varied from a maximum of 100% of V_S at a trigger angle $\alpha = 0$ to a low of 70.7% of V_S at $\alpha = \pi$ Radians.

These drawbacks can be overcome by using a single phase full wave ac voltage controller.

THANK YOU

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